

[54] **METHOD FOR PRODUCING URANIUM
ATOMIC BEAM SOURCE**

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[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

A method for producing a beam of neutral uranium atoms is obtained by vaporizing uranium from a compound UM_x heated to produce U vapor from an M boat or from some other suitable refractory container such as a tungsten boat, where M is a metal whose vapor pressure is negligible compared to that of uranium at the vaporization temperature. The compound, for example, may be the uranium-rhenium compound, URe_2 . An evaporation rate in excess of about 10 times that of conventional uranium beam sources is produced.

7 Claims, No Drawings

METHOD FOR PRODUCING URANIUM ATOMIC BEAM SOURCE

The invention described herein was made in the course of, or under, Contract No. W-7405-ENG-48, with the U.S. Atomic Energy Commission.

BACKGROUND OF THE INVENTION

This invention relates to isotopic separation processes for uranium, and more particular to a method for producing a beam of neutral uranium atoms by vaporizing uranium from a uranium containing compound.

The separation of the isotope U^{235} (which is fissionable by neutrons) from natural uranium, a binary mixture containing mainly non-fissionable U^{238} , or simply the enrichment of the mixture in U^{235} are extremely important processes for nuclear applications. The process now used on an industrial scale is the separation by diffusion through a porous barrier, although a number of other processes have been used or suggested including electromagnetic separation (the so-called "calutron" separation), separation by centrifugation, and by thermal diffusion.

More recently isotopic separation by laser has been proposed wherein uranium vapor is irradiated by laser light to preferentially excite the U^{235} isotope, as exemplified by U.S. Pats. No. 3,443,087, issued May 6, 1969 and No. 3,558,877, issued Jan. 26, 1971, and by French Patent No. 2,094,967 published Apr. 2, 1972.

Isotopic separation by laser light requires a source of neutral uranium atoms "intense" enough to provide a uranium vapor pressure of about 10^{-2} torr for periods of several hours. Conventional beam sources, in which uranium metal is resistively heated in a tungsten boat, are not practical for this purpose since molten uranium is highly corrosive to tungsten. At 2000°K , where the uranium vapor pressure is barely adequate, a tungsten boat will last only a few minutes. Arc-melting and electron-beam melting are not desirable because these methods create uranium atoms in an excited state rather than the required neutral atoms. Also, a prior known process for producing a beam of neutral uranium atoms, described in J. Chem. Phys., Sept. 1, 1972, page 1975, involved an atom beam source in which uranium metal is vaporized from a tungsten filament.

SUMMARY OF THE INVENTION

The present invention is directed to a process for producing a uranium atomic beam source by vaporizing uranium from a UM_x compound contained in an M boat, such as URe_2 contained in a rhenium boat, or by vaporizing uranium from a UM_x compound, such as URe_2 , contained in a tungsten boat. The invention produces uranium atomic beams of the required "intensity" and duration for use in laser isotope separation processes.

Therefore, it is an object of this invention to provide a method for producing a uranium atomic beam source.

A further object of the invention is to provide a method for producing a beam of neutral uranium atoms by vaporizing uranium from a uranium compound, such as uranium-rhenium, the compound being contained in a corresponding type metal boat or contained in a tungsten boat, or in some other suitable refractory container.

Other objects of the invention will become apparent from the following description.

DESCRIPTION OF THE INVENTION

This invention involves a method for producing uranium atomic beams of the required intensity and duration for use in isotope separation processes in which uranium vapor having a pressure of about 10^{-2} torr is irradiated by laser light to preferentially excite the U^{235} isotope. The method broadly consists of vaporizing uranium from a uranium-bearing compound (UM_x) where M is a metal whose vapor pressure is negligible compared to that of uranium at the vaporization temperature, the compound being in an M boat or contained in tungsten boats. Possible choices for M are rhenium, osmium, iridium, and niobium (niobium forms a solid solution with uranium). While the following description of examples and operational sequences is directed to rhenium as the metal M in a uranium-rhenium compound URe_2 in a rhenium boat or coated on tungsten filaments, it is not intended to limit the invention to this specific compound. The invention will be described first using the URe_2 compound in a rhenium boat, followed by a description of URe_2 coated tungsten filaments.

The method consists simply of vaporizing uranium from the uranium-rhenium compound URe_2 from a rhenium boat. At a typical operating temperature of 2300°K , the vapor in equilibrium with URe_2 consists almost entirely of uranium atoms rather than URe_2 molecules. The known vapor pressure of rhenium, 10^{-7} torr, is sufficiently low at this temperature that vaporization of rhenium from the boat itself is minimal. Furthermore, the melting points of pure rhenium, 3453°K , and of the Re- URe_2 eutectic, 2380°K , are sufficiently high as to suitably contain that compound. Details for carrying out an example of the method and results of such are as follows

EXAMPLE

Chips of uranium metal were arc-melted with a stoichiometric excess of rhenium powder (to preclude free uranium in the product) to form URe_2 . 0.36 gram of powdered URe_2 was placed in a 0.1 mm thick rhenium (Re) boat located in a vacuum chamber and resistively heated by passing a current of 100 amps at 3.4 volts through the boat. Operating pressure of the vacuum chamber was 10^{-6} torr, and evaporation temperature (as determined by optical pyrometer corrected for window-attenuation) was 2300°K . After operation for more than one hour, the vacuum chamber was cooled and the rhenium boat plus URe_2 charge was weighed. The URe_2 weight loss corresponded to an average evaporation rate of $50\text{ mg/cm}^2\text{-hr}$ based upon a boat evaporation area of 0.4 cm^2 . This evaporation rate is about ten times faster than conventional uranium beam sources using tungsten boats. There was no observable corrosion of the rhenium boat.

As thus shown, in its broadest aspect, the above described method involves a source which is capable of producing a uranium atomic beam in which a compound UM_x is heated to produce U vapor from a M boat, with M being, as pointed out above, osmium, iridium and niobium, as well as rhenium. In the U-Re system, URe_2 is the only compound that exists in equilibrium with Re metal itself, and a high eutectic temperature (2380°K) exists between Re and URe_2 ; also, Re and URe_2 have low mutual solubilities. This permits

the use of an Re boat to contain the URe_2 , with negligible corrosion.

The method for utilizing a UM_x compound contained in a tungsten boat rather than in an M boat is as follows

EXAMPLES

A tungsten boat resistive heater, 0.25 mm thick, with a hot zone 9 mm wide by 40 mm long, and having a 1 mm depression for sample containment, was loaded with 0.59 g of coarse URe_2 powder which was spread out over $\sim 0.6 \text{ cm}^2$ of boat area. The sample was heated under $\sim 10^{-6}$ torr vacuum for 23 min. at $\sim 2170^\circ\text{C}$ as observed in the hottest part (the center) of the heater. The central portion, containing \sim one third of the sample was observed (through an optical pyrometer) to melt, and to remain molten throughout the run. The weight change of the sample gave an average weight loss rate of $\sim 50 \text{ mg/cm}^2\text{-hr}$, and a metallographic cross section of the molten region showed negligible attack of the tungsten boat although the melt had wet and spread slightly on the tungsten surface. This run demonstrated the good corrosion resistance of tungsten to solid or molten URe_2 , and showed how URe_2 may be applied as a coating to tungsten surfaces to fabricate filament vapor sources.

Subsequent work has now shown that a corrosion resistant barrier of $\sim 25 \mu\text{m}$ thickness forms on tungsten surfaces in contact with molten URe_2 . These experiments were conducted at temperatures above the melting point of URe_2 (2170°C), this being due to the higher operating temperature possible with a tungsten boat without significant corrosion of the tungsten by molten uranium rhenide or uranium vapor. Corrosion of tungsten by both molten URe_2 and uranium vapor has been shown to be negligible in heatings up to temperatures as high as 2600°K for more than one hour, where the uranium vapor pressure at 2550°K is found by rate of weight loss and mass spectrometry to be 0.010 torr within the heater chamber, and 0.005 torr (corresponding to $320 \text{ mg/cm}^2\text{-hr}$) at the orifice of the chamber. Mass spectrometric analyses of the effusing vapor at $2100^\circ\text{--}2600^\circ\text{K}$ has also established that atomic uranium represents more than 90% of the uranium containing vapor constituents.

It has thus been shown that the present invention provides a uranium atomic beam source, and particularly a method for producing a beam of neutral uranium atoms by vaporizing uranium from a uranium bearing compound such as URe_2 contained in an ap-

propriate boat of similar metal or coated on a tungsten filament, or contained in a tungsten boat, thereby providing an evaporation rate in excess of about ten times that of conventional uranium beam sources.

While particular examples and operational sequences for carrying out the invention have been described, modifications and changes will become apparent to those skilled in the art, and it is intended to cover in the appended claims all such modifications and changes as come within the spirit and scope of the invention.

What I claim is:

1. A method for producing a beam of neutral uranium atoms comprising the step of vaporizing uranium from a uranium-bearing compound composed essentially of uranium and a metal M whose vapor pressure is negligible compared to the vapor pressure of uranium at vaporization temperature and selected from the group consisting of rhenium, osmium, iridium, and niobium.

2. The method defined in claim 1, wherein the step of vaporizing the compound is carried out by placing a quantity of the compound in a boat of the metal M, and heating the boat.

3. The method defined in claim 1, wherein the step of vaporizing the compound is carried out by containing the compound in a tungsten boat, and heating the compound.

4. The method defined in claim 1 wherein the compound is URe_2 .

5. The method defined in claim 4, wherein the step of forming the URe_2 compound is accomplished by arc-melting chips of uranium metal with a stoichiometric excess of rhenium powder.

6. The method defined in claim 4, wherein the step of vaporizing the URe_2 compound is carried out by placing a selected quantity of powdered URe_2 in a rhenium boat of selected thickness, placing the boat in a vacuum chamber, and resistively heating the URe_2 by passing electric current through the boat causing vaporization of the uranium from the URe_2 compound.

7. The method defined in claim 4, wherein the step of vaporizing the URe_2 compound is carried out by containing the compound in a tungsten boat, placing the tungsten boat in a vacuum chamber, and resistively heating the URe_2 by passing electric current through the tungsten boat causing vaporization of the uranium from the URe_2 compound.

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